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A Brief History of Weights and Measures

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A BRIEF HISTORY
of
WEIGHTS AND MEASURES

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PREFACE

In the following pages it has been the aim to present in simple and non-technical langauge, so far as possible, a comprehensive view of the evolution of weights and measures. Realizing that in the history of mankind there have been many hundreds of systems of weights and measures, no attempt is made to discuss all of these. Since in every measurement system there are dozens of different units, the discussion in this paper is limited to the most common units of linear, capacity, and weight measurement. It has been the intention to consider briefly and systematically the general history of weights and measures, the scientific methods by which units and standards have been determined, and present aspect of modern systems of weights and measures, together with the difficulties and advantages in them.

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CHAPTER I

PREHISTORIC METHODS OF MEASUREMENT

To discover the origin of measure it is necessary to go back to the very beginning of the human race. Although we have no written records to go by one can easily imagine what the original measurements must have been like. No doubt the earliest measure involved no standard units at all. When a cave man wished to make a spear exactly the same size as his neighbor's, he could measure his spear by his neighbor's spear. Even today the old-fashioned Chinese shoemaker uses no measuring units in making a pair of shoes. He asks his customer to put his foot on a strip of paper and makes an outline of his foot.

In time, our prehistoric ancestors learned that this method of measurement would not work in all situations; thus a better system was needed. Let us again take the example of making a new spear the same size as an old one by comparison. If for some reason the spears could not be compared directly then prehistoric man may have compared the spear length to his arm and finding this not long enough added the width of his other hand. He unknowingly had begun to establish a standard unit of measure for himself.

It is believed that from early body measures came four basic units of linear measure. These units were the "cubit" (the distance from the point of the elbow to the tip of the middle finger), the "span" (the distance from the end of the thumb to the tip of the little finger of the outspread hand), the "palm" (the breadth of the four fingers), and the "digit" (the breadth of the first finger or the middle finger).[1]

During the time that these short linear units were being developed it became necessary to express great distances. No doubt these were expressed in time rather than linear units. If a cave man wished to describe the distance from his cave to a hunting ground, he might say it this way, "It is from sunrise to sunset". Even today we use this method when we say a house is located ten minutes from the business district. For a distance too long to be defined in terms of body measurements and too short to be expressed in days, early man may have given the distance in terms of "paces" or "steps".[2]

1Committee on Materials of Instruction of the American Council on Education, The Story of Weights And Measures, American Council on Education, 1932, p. 5-7

2Hallock, William; Wade Herbert T., The Evolution of Weights And Measures and The Metric System, The Macmillan Company, New York, 1906, p. 1-2

Shortly after the prehistoric man began to use linear measurement he found it necessary to weigh things. Perhaps the first measurement of weight was in terms of how much a man could carry. Actually this wasn't really determining weight as much as it was size. The first type of balance used was probably a human balance. Weights could be compared by balancing small objects, one in each hand, and guessing whether one was heavier or whether the two weighed about the same. It was a long time before some one thought of a weighing machine--a stick hanging by a cord tied around its middle. The objects that were being weighed were hung on other cords, one at each end of the stick. If they balanced, the stick stayed parallel to the ground. If one was heavier, the stick dipped on that side. It wasn't until barter became a common practice that the ancients decided they needed a standard unit of weight by which all things could be compared.

It is doubtful if cave man had any knowledge of area measure. Very little was known about volume measure with the exception of comparison of sizes.[3]

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[3]Bendick Jeanne, How Much And How Many, Whittlesey House, McGraw-Hill Book Company, Inc., 1947, p. 14-16

CHAPTER II

MEASURING SYSTEMS OF ANCIENT CIVILIZATIONS

As thousands of years passed man eventually became civilized and as he progressed so did his method of measurement. In ancient Babylonia man began to study the science of astronomy and found that he needed a better system of weights and measures. The Babylonian measurement system was sexagesimal in nature. This no doubt arose from their division of a circle into 360 parts. The first discovery of Babylonian measurement came from the study of the Senkereh Tablet found in 1850 and believed to date back to 2500 B.C. Other discoveries indicated that at least three different lengths for the standard cubit were used.

In 1881 a statue of King Gudea in a position of prayer was discovered. On his knees a slab of stone was found on which is engraved the ground plan of a palace and a double line representing a scale of measure. It is believed that this was the Babylonian scale of measure in about 2100 B.C. By using the two stones scientists have reached the following conclusions on the scale of measure. Five handbreadths or palms equaled one cubit, six cubits equal one "reed", 12 cubits equal one "gar", 60 gar equals one "ush", and 30 ush equals one "kasbu". The last unit, the "kasbu", is approximately equivalent to the present day 21 kilometers.

For fundamental units it is possible and most convenient to start with the unit of length and develop from it units of weight and capacity by taking a volume equal to that of a cube, each side of which is equal to the selected unit of length, and then filling it with water, as was done with the modern metric system. This feature is claimed for the weights and measures of the ancient Babylonians remembering it was based on six and not ten as our present metric system is. The Babylonian capacity measures started with the cube whose edge was a handsbreadth in length and which when filled with water gave the unit of weight, the great "mina". The unit of capacity was known as the "ka". Breaking down the units of weight finds an interesting relationship between two natural units of weight, water and grains of corn. The mina was composed of 60 "shekels" and the shekels each contained 360 "she" or grains of corn. For a greater weight 60 mina was made equal to one "talent". The word talent in later history came to mean many things.

Babylonians had also units for area and had a fairly accurate water clock. Even though there were many different systems of measurement with entirely different bases these ancient people showed amazing progress in the science of metrology.[4]

Paralleling the development of the Babylonian civilization was the development of civilization in Egypt. Many historians disagree as to the origin of the Egyptian system. By reading the ancient Greek historian Herodotus we would be led to believe the Babylonian system came first. He speaks of the royal cubit of Babylon and compares it to the Greek cubit.[5]

Regardless of which came first the Egyptian measuring system like that of the Babylonians is based on body measurements. Measurements of the great pyramid which dates back to 4,000 B.C. find the rooms to have lengths and widths in an equal number of cubits. Pictures of balances adorned the walls of some of the oldest pyramids and many different units of weight have been found written in hieroglyphics on stone tablets. Perhaps the greatest improvement in weighing made by the Egyptians was the use of standard weights made of stones. Through the years the names and bases for weights and measures

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[4]Hallock, The Evolution of Weights And Measures and The Metric System, p. 14-16

[5]Berriman A.E., Historical Metrology, J.M. Dent & Sons Ltd, 1953, p. 73

changed through new uses of them and the influence that conquerors had upon the country. There is far too much confusion to attempt to single out any one set of names and values to refer to as the Egyptian system of measures.[6]

As the center of civilization moved so did the dominating measuring system of the time. In period of history between 500 B.C. and 300 B.C. Greece was the principal power of the world. Among the many contributions to mankind made by Greece was a new standard unit of length. The fundamental unit of Greek linear measurement was the foot. This foot was equal to 12.1375 inches of modern measurement. Even in Greece however there were many holdovers from the Babylonian measuring system and one of these was the royal cubit. The cubit was $1\frac{1}{2}$ times as great as the foot and when multiplied by four gave the "fathom", which is the distance between the tips of the fingers when the arms were extended. The fathom multiplied by 100 gave the "stadion", originally the distance that a strong man could run without stopping for breath. This stadion was equal to 400 cubits or 600 feet.

The Greek unit of weight was copied from the Babylonians. However, a cube a handsbreadth on a side was used rather than a cube one cubit on a side. They

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6Hallock, The Evolution of Weights and Measures and The Metric System, p. 22-24

used the word "talent" for their unit of weight as did the Babylonians. In the subdivisions of weights the Greeks introduced the duodecimal (base 12) system. In many ancient writings we find the word talent used as a sum of money. This came logically for a "talent of silver" was that weight of silver. Changes came in standard units as different rulers came into power until eventually the Greek system became almost as confusing as the Egyptian.[7]

It was most natural that the measures of Greece should pass to Rome, and we find between the two a close connection. The principle of subdivision was duodecimal, and we find the Greek foot introduced as a unit of length. The unit of Roman weight was the "as", divided into twelve "unciae". Our English words ounce and inch came from the latter.

Perhaps the foot is the most important of the Roman measures, as it not only extended throughout Europe as a fundamental unit, but in some form it has survived almost everywhere until supplanted by the meter. The Roman weights, measures and coinage, by virtue of the conquests and influence of the empire, found their way all over Western Asia and Europe; and with

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[7]Hallock, The Evolution of Weights and Measures and The Metric System, p. 25-27

the decline of the imperial power formed the foundation for local systems. However, with the lack of interest in science which soon began to characterize the age and the general decline of culture, weights and measures were no longer maintained in conformity with any system or with any due regard to primary standards. Consequently, there was a distinct corruption of measures, and until the revival of experimental science in the middle ages little attention was paid to the subject. Indeed, all standards and systems were practically neglected, and by the sixteenth century there was virtually a return to the body measures throughout Europe.[8]

8Hallock, The Evolution of Weights and Measures and The Metric System, p. 26-28

CHAPTER III

ORIGIN AND DEVELOPMENT OF THE METRIC SYSTEM

After several hundred years during the middle ages which found each town using its own method of measurement, the French began the task of devising a universal system of measurement. In 1670 Gabriel Mouton, Vicar of St. Paul's Church, Lyons, first proposed a comprehensive decimal system having as a basis the length of an arc of one minute of a great circle of the earth. Shortly after this, a great battle began among the scientists in France to agree upon the basic unit. In 1671 and 1673, Pickard and Huygens announced that the length of a pendulum beating seconds in Paris should be the basic unit, the pendulum being divided into three parts known as feet.

The idea for a universal measurement system based upon an unvarying standard was certainly a good one, but an acceptable standard was difficult to agree upon. During the Eighteenth century many basic units were proposed but finally all ideas were reduced to the seconds pendulum and a segment of a great circle on the earth. It was pointed out that the length of the seconds pendulum varied with the force of gravity, so that in different parts of the world the length of the pendulum would not be the same. Those on the other side felt that since an accurate measurement of a body so large as the earth would be practically impossible, an accurate standard could not be established.

At last, in 1792 a committee from the French Academy of scientists began the work that was to eventually be approved by the government. Delambre and Mechain measured the distance between Dunkirk and Barcelona. These towns were chosen because of their sea level location and because of the fact that the distance measured would cross the 45th parallel. Since mountains had to be crossed the measurement was extremely difficult. In many cases triangles were used to determine a distance and while the end result showed an accurate measurement it was by no means made in a straight line between the two cities. With this measurement the length of an arc between the north pole and the equator could be determined. This distance, one-fourth of an arc of a great circle, was subsequently divided into 10,000,000 parts and the basic unit of the metric system was established. The reason given for not using the seconds pendulum as the standard was that it involved time and was a non-linear element.[9]

9Hallock, The Evolution of Weights and Measures and The Metric System, p. 43-60

In 1793, a brass bar was made equal to the new standard which had been named the "meter". In 1795, a law was passed in France legalizing the metric system. However, in 1812 under the rule of Napoleon a new system of measures was legalized. This system kept the basic unit of a meter but divided it into fractional parts using more popular and common names for them. Fortunately in 1837, the law of 1812 was abolished and France again reverted to the decimal system with the basic unit the meter. In this legal action of 1837 the country was given three years to convert to the decimal metric system and after 1840 it would be a criminal offense to be found using any other system of measures.[10]

The basic unit of one meter was divided into many units using the decimal system. The prefixes used for the names came from the Latin, thus: one millimeter is 1/1000 meter; one centimeter is 1/100 meter; one decimeter is 1/10 meter; one dekameter is 10 meters; one hectometer is 100 meters; and one kilometer is 1,000 meters. These prefixes were used in units of weight and volume.[11]

When the French threw aside all their old measures and made a whole new measuring system, they first worked

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10Berriman A. E., Historical Metrology, p. 143-144

11Bendick Jeanne, How Much And How Many, p. 158

out their units of length. They began with units of length because they knew that having once established measures of length, they could easily make from them the other measures they needed.

To get units for measuring surface, they had only to square their units of length. Thus, in the metric system surface is measured in square meters, square centimeters, square millimeters etc. For measuring land, the square hectometer (a hectometer is one hundred meters) is often used. To get units for measuring volume, they cubed their units of length. Volume is thus measured in cubic millimeters, cubic centimeters, or cubic meters.

For the unit for measuring weight, they took the weight of one cubic centimeter of pure water at the temperature of four degrees Centigrade and called it a "gram". A platinum weight was made which was as nearly as possible the weight of one thousand cubic centimeters of water, and this platinum weight became the standard kilogram (one thousand grams).

As the chief unit of volume the liter was adopted. A liter measure holds one thousand cubic centimeters of the material which is being measured. Another way of defining a liter is to say that it is the capacity of a vessel which holds exactly one kilogram of water at the temperature of four degrees Centigrade.[12]

12American Council on Education, The Story of Weights and Measures, p. 16-17

It had been very difficult to get a decimal system of measures adopted in France and one can imagine it was even more difficult to get the world to adopt this system. In Europe during the early nineteenth century many different systems of weight and measures were being used. It didn't take long for the scientists of the various countries to see the advantage of the metric system, but the governments were strongly against change. Only the small countries of Switzerland and Holland adopted the metric system in the early part of the nineteenth century.

After 1837 the French government made its first effort to get universal adoption of the metric system for trade purposes. France sent copies of its standards to all the countries in the world and a general feeling of favor for the system began to spread throughout the world. In 1851, at the London Exposition, the first real steps for the adoption of the metric system were taken. Here not only scientists but economists and statesmen were congregated. These men formed an international association with the purpose of advancing the adoption of a single system of weights and measures. This association made an examination of the different systems employed throughout the earth, and decided that the metric system, on account of its scientific character and general availability for international trade, was to be preferred, and accordingly made a recommendation in its favor.

During the latter part of the nineteenth century almost every country in the world adopted the metric system. Only the United States and the British Empire do not use the metric system today. However, these two countries use it in scientific work and it has gradually come into a more general use. Although much legislation has been attempted, until the present time the two countries have refused to pass laws making it compulsory.

CHAPTER IV

ORIGIN AND DEVELOPMENT OF THE ENGLISH SYSTEM

The story of the English measures of length is chiefly the story of attempts to have the same measures used throughout England and to have these measures mean exactly the same wherever they were used. As was experienced in other countries this was difficult to accomplish.

Although the British system of measures has many origins many of the units date back to the time of the Roman conquest. Perhaps the first attempt at standardizing the units of length was made by Henry I. He decided that the standard yard was to be the distance from the tip of his nose to the end of his thumb. This standardization was a failure and in the fifteenth century Parliament based a new system on the inch. The inch was to be determined by laying three grains of barley end to end. The grains were to be dry and were to be taken from the middle of the ear.[13]

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[13]American Council on Education, The Story of Weights and Measures, p. 12

In 1496 during the reign of Henry VII a brass bar whose length furnished the standard distance was introduced. This was used as the standard until 1588, when in the reign of Queen Elizabeth, a new standard yard, also of brass, was constructed, which is still in existence after having served for a long period. In spite of many such attempts to make the measures of length the same throughout all England, not very much was accomplished until late in the eighteenth century.

In 1760 John Bird carefully made a number of metal yard measures and these were sent to various parts of the country. In 1824 this length was finally approved as the standard yard and might be in existence today were it not for a fire in 1834 destroying the original.[14]

The British imperial yard today is defined as the distance, at 62 degrees Fahrenheit, between two fine lines engraved on gold studs sunk in a specified bronze bar known as the Number One standard yard. This bar was cast by Troughton and Simms in 1845.[15]

The development of standard units for weight and volume followed much the same pattern as the yard. During the Elizabethean era standard weights of two systems were prepared. These sets of weights, one avoirdupois and the

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[14] Hallock, The Evolution of Weights and Measures and The Metric System, p. 243-244

[15] Encyclopedia Britannica, Encyclopedia Britannica, Inc., Chicago, 1953, Volume 15, p. 135

other Troy, ranged from 1/16 of an ounce to 56 lbs. and were made of bronze. The weights served as the English standard from 1588 to 1824.[16]

Today the British imperial pound is defined as the mass of a cylinder of pure platinum about 1.35 in. high and 1.15 in. diameter. This is the only pound legal for use in Great Britain and is sometimes called the avoirdupois pound, the Troy pound having been abolished with other Troy weights in 1879, by the Weights and Measures Act. The only exception made for Troy weights was the ounce and its decimal parts, legalized again in 1853 for use in the sale of gold and silver articles, platinum and precious stones.[17]

It would be difficult to try to mention all the units that have been used in England for capacity measurement. Of all of these, the gallon and the bushel are the most important. In 1824, after many years using various items as standards, Parliament adopted the imperial gallon and bushel. The gallon and the bushel, are based on the fact that an imperial gallon represents the volume occupied by ten pounds of distilled water at 62 degrees Fahrenheit and a barometric pressure of 30 inches, while the bushel is eight gallons.[18]

16Hallock, The Evolution of Weights and Measures and The Metric System, p. 244

17Encyclopedia Britannica, Volume 15, p. 136

18Hallock, The Evolution of Weights and Measures and The Metric System, p. 249

The system of measurement used in the United States is called the English system but differs in a few ways from the system used in England. The American colonists had brought from England measures of weight and capacity as well as measures of length. Since England used different standards in different parts of the island this of course led to the fact that not all measures were exactly the same throughout the colonies.

After securing Independence from England the United States gave the government the power of determining the standards of weights and measures. This power came first in the Articles of Confederation and later in the constitution.

Our government was slow in using the power and it was several years before a system was adopted. Thomas Jefferson was one of the wise men to propose a decimal system based on the pendulum. Although he got some backing this system was never adopted.[19]

In 1828 the government accepted the English Troy pound for use in the minting of money and a few years later adopted the avoirdupois pound also. At the same time, it was decided that the standard gallon was to be 231 cubic inches and that the standard bushel was to be 2,150.42 cubic inches. Oddly enough, the gallon and the bushel which our government decided to accept as standards were measures

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19Hallock, The Evolution of Weights and Measures and The Metric System, p. 109-112

which the English government had discarded some years before. We still use these measures. Thus, our measures of capacity are not the same as the present English measures of capacity even though they have the same names.[20]

In 1899 the United States received an accurate copy of the French kilogram and meter. The international meter and kilogram were adopted as fundamental standards, but the customary units, the yard and the pound, were derived from them. This meant no change in the value of the pound or yard but a change in the standard to which they were compared.

Until the present time the United States version of the English system has successfully withstood the challenge of the metric system.[21]

20American Council on Education, The Story of Weights and Measures, p. 30-31

21Hallock, The Evolution of Weights and Measures and The Metric System, p. 130

CHAPTER V

COMPARISON OF THE ENGLISH AND METRIC SYSTEMS

Seventy-five percent of the people in the world today use the metric system of measurement while most of the remainder use the English system. Fifty-five of the largest fifty-seven nations use the metric system, leaving the United States and England as the two non-conformists. There must be some sound reasons for this large majority being in favor of the metric system.

One of the first differences an individual finds when comparing the metric system with the English system of weights and measures is in the definition of the units. The basic unit, the meter, is defined as a part of a natural unit, the quadrant of a meridian of the earth; therefore it could be determined again if it were ever destroyed. In the English system this would be practically impossible.

The second difference noted in the two systems is the relation between consecutive units. The metric system has the decimal division within its units, a fact which makes for economy in learning as well as in computation. Changing from one unit to any other unit in the metric system is really a matter of moving the decimal point to the right or left, a process which involves multiplication or division by 10 or some power of 10. One illustration will be sufficient to convince the ordinary individual that the metric units operate with greater ease than the English units.

137 centimeters = 13.7 decimeters = 1.37 meters
137 inches = 11 5/12 feet = 3 29/36 yards

The third difference observed between the two systems of measurement is the terminology. In the metric system the three words, "meter", "liter", and "gram" are the basic terms. In addition there are six prefixes, three for multiples and three for decimal parts. The three multiples are the Greek terms "deka", "hecto", and "kilo", meaning "ten", "one hundred", and "one thousand" respectively. The three prefixes for decimal parts are "deci" (one tenth), "centi" (one-hundredth), and "milli" (one-thousandth). The English system is lacking in this respect. For instance, the linear units--the inch, foot, yard, rod and mile--do not indicate the part that one unit is of any other unit. The terminology is difficult.

The fourth difference is the interrelation between the units. In the metric system the basic units are related to each other, a fact which makes for economy in computation. The English system contains no such relationship. In the metric system we find 1 cubic centimeter of water equal to one mililiter of volume and weighing one gram. It is then easy to go from weight to volume or from linear measure to weight for any material if the specific gravity is known. All the computations involve moving decimal points.[22]

Many people in the United States and England are aware of the advantages of the metric system and are attempting to get its adoption in their respective countries. In the United States many hundreds of organizations have approved the adoption of the metric system. In 1926 a bill was introduced in Congress to change from the English system of measures to the metric system, but it failed to pass by a few votes. Since that time no actual attempts in Congress have been made.

With scientists in both England and the United States using the metric system and with many grade school text-books now teaching it, the possibilities for its adoption are very favorable. Perhaps in a few decades the entire world will be using the weights and measures of the metric system.[23]

22Committee on the Metric System, Johnson J.T., Chairman, The Metric System of Weights and Measures, Bureau of Publications Teachers College, Columbia University, 1948, p. 291-292

23Ibid, p. 287

COMMON UNITS OF THE ENGLISH SYSTEM

Length

12 inches	=	1 foot
3 feet	=	1 yard
$16\frac{1}{2}$ feet	=	1 rod
5280 feet	=	1 mile
1760 yards	=	1 mile

Capacity

2 pints	=	1 quart
4 quarts	=	1 gallon
8 quarts	=	1 peck
4 pecks	=	1 bushel

Weight

16 avoirdupois ounces	=	1 pound
2000 pounds	=	1 ton (short)
12 Troy ounces	=	1 Troy pound

COMMON UNITS OF THE METRIC SYSTEM

Length

1000 millimeters	=	1 meter
10 millimeters	=	1 centimeter
100 centimeters	=	1 meter
1000 meters	=	1 kilometer

Capacity

1000 milliliters	=	1 liter
100 milliliters	=	1 deciliter
10 deciliters	=	1 liter
1000 liters	=	1 kiloliter

Weight

1000 milligrams	=	1 gram
1000 grams	=	1 kilogram
1000 kilograms	=	1 metric ton

CONVERSION TABLE FOR THE COMMON UNITS OF THE ENGLISH AND METRIC SYSTEMS

Length

1 centimeter = 0.394 inches	1 inch = 2.540 centimeters
1 meter = 3.28 feet	1 foot = 0.305 meters
1 kilometer = 0.621 miles	1 mile = 1.853 kilometers

Capacity

1 milliliter = .034 U.S. fluid ounces
1 liter = 1.057 U.S. liquid quarts
1 liter = 0.264 U.S. gallons

1 U.S. fluid ounce = 3.697 milliters
1 U.S. liquid quart = 0.946 liters
1 U.S. gallon = 3.785 liters

Weight

1 gram = .035 avoirdupois ounces
1 kilogram = 2.205 avoirdupois pounds
1 metric ton = 1.102 short tons

1 avoirdupois ounce = 28.350 grams
1 avoirdupois pounds = 0.454 kilograms
1 short ton = 0.907 metric tons

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